Changes in seabird populations breeding on Small Island, Wadham Islands, Newfoundland

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Atlantic Region
Canadian Wildlife Service
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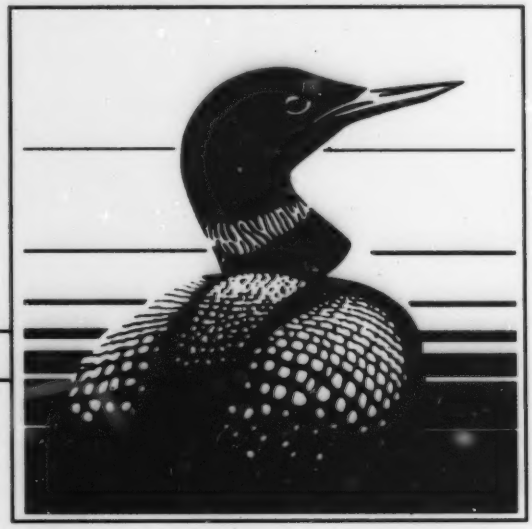

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CHANGES IN SEABIRD POPULATIONS BREEDING ON SMALL ISLAND, WADHAM ISLANDS, NEWFOUNDLAND

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Summary

Numbers of breeding seabirds on Small Island, in the Wadham Islands, off the northeastern coast of Newfoundland, were estimated in July 2001. Based on hole counts and their occupancy rates an estimated 6 190 ± 355 (5 453 – 6 939; 95% CI) pairs of Atlantic Puffin (*Fratercula arctica*) bred on Small Island in 2001; a reduction of 59% since 1984. Based on the densities of occupied burrows and the total occupied area, an estimated 1 038 ± 255 (506 – 1 571; 95% CI) pairs of Leach's Storm-petrel (*Oceanodroma leucorhoa*) bred in 2001; a 92% reduction since 1984. The appearance of a small Great Black-backed Gull (*Larus marinus*) colony on this island in the early 1980s may explain the reduction in petrels and puffins. In contrast, Razorbills (*Alca torda*) increased dramatically from 15 pairs breeding in 1984 to a minimum of 194 breeding in 2001. Razorbills are not susceptible to predation by gulls, and, as with Razorbill populations elsewhere, the population has increased on Small Island.

Résumé

La population des oiseaux de mer nicheurs de l'île Small dans l'archipel Wadham, au large de la côte nord-est de Terre-Neuve, a été évaluée en juillet 2001. D'après le décompte des terriers et leur taux d'occupation, il est estimé que 6 190 ± 355 (5 453 – 6 939; CI de 95 %) couples de macareux moines (*Fratercula arctica*) ont niché en 2001 dans l'île Small, ce qui représente une diminution de 59 % depuis 1984. D'après la densité des terriers occupés et la superficie totale occupée, environ 1 038 ± 255 (506 – 1 571; CI de 95 %) couples d'océanites cul-blanc (*Oceanodroma leucorhoa*) y ont niché en 2001, ce qui correspond à une réduction de 92 % depuis 1984. L'apparition d'une petite colonie de goélands marins (*Larus marinus*) qui avait élu résidence dans cette île au début des années 1980 pourrait peut-être expliquer la chute du nombre d'océanites et de macareux. En revanche, la population de petits pingouins (*Alca torda*) a augmenté de façon dramatique, passant de 15 couples nicheurs en 1984 à un minimum de 194 couples nicheurs en 2001. Les petits pingouins ne sont pas sensibles à la prédation par les goélands et, comme c'est le cas ailleurs, la population de petits pingouins a aussi augmenté dans l'île Small.

1. Introduction

The coasts of Newfoundland support some of the largest seabird breeding colonies in North America (Montevecchi and Tuck 1987, Cairns et al. 1989). Major changes have occurred in the marine ecosystem around Newfoundland, and seabird populations have responded to these impacts (Cairns and Verspoor 1980, Robertson et al. 2001). They include changing forage fish distributions, fisheries, bycatch, mortality from chronic oil pollution, hunting, colony disturbance and, changing predator distributions (Montevecchi and Tuck 1987, Chapdelaine et al. 2001, Montevecchi 2002). As part of ongoing monitoring efforts, the breeding seabirds of Small Island, in the Wadham Island group, northeast Newfoundland, were inventoried in the summer of 2001. Small Island was chosen to represent a smaller breeding colony for which some historical data was available to assess population change.

Results of the 2001 survey for breeding Atlantic Puffins (*Fratercula arctica*), Leach's Storm-petrel (*Oceanodroma leucorhoa*) and Razorbill (*Alca torda*) are presented in this report. Results from earlier surveys (particularly 1984) are also compiled and compared with these recent estimates. Finally, factors driving changes in the size of breeding populations are considered.

2. Study site

Small Island (49° 35' N, 53° 46'W), along with Offer Wadham Island, is at the seaward edge of the Wadham Islands group, 20 km northeast of Musgrave Harbour, Newfoundland (Figure 1). It is a relatively small (520 m x 360 m) island, and low-lying (highest point only 10 m asl). The edge of the island consists of boulder slab, with some boulder scree, while the interior contains meadows and low-lying shrub. Scotch Lovitch, Rye Grass and Cow Parsnip predominate in areas of puffin burrows. Further descriptions of the island are available in Cairns and Verspoor (1980) and Russell and Montevechi (1996).

3. Methods

Fieldwork was conducted from 3 to 6 July 2001.

3.1 Atlantic Puffin

To assess puffin numbers, we counted all visible holes around the island. Holes were defined as any suitable entrance to what could conceivably lead to a puffin burrow. Holes were counted by observers walking in parallel, about 2-5 m apart, in areas of potential puffin habitat. Observers followed a transect and counted all visible holes to one side of them. The observer on the outside of the transect laid out a line of coloured flags to define the limit of the current transect. At the next transect, that observer counted only to the previously defined line and the observer at the other outer edge laid down a new line of flags. In this way, all holes on the island were counted.

Locations of 20 randomly placed 30 m^2 plots were then chosen to assess occupancy rates of holes. Each plot was chosen by randomly selecting two grid coordinates and determining whether the corresponding site fell within areas of occupied puffin habitat. If it did, it was sketched on to a map. The location of each plot

was based on these map locations. Once the general location was reached, a 1 m pole was put in to the ground and the plot was established from this central point. Circular plots and were marked with a can of spray paint tied to a cord 3.09 m long. This method drew a circle of 30 m^2 on the ground within which all holes were examined for their contents (i.e. grubbed). Standard data sheets were used and holes were classified into the following five categories; unknown (in which the end of the burrow could not be reached), entrance to another burrow, a short burrow (< 30 cm) that was not of sufficient length to accommodate a breeding puffin, an empty burrow, or an occupied burrow. Occupied burrows contained an egg, a chick, an adult, an adult with it's chick or egg, or other evidence of occupancy such as nest material, chick faeces or egg shells from the current season. Burrows were defined as occupied burrows plus empty burrows.

The sample was stratified into either vegetated and barren peat areas or the large area of burrows in bare gravel/sand on the southeast side of the island. This area had a high density of holes during the hole count and may have had many holes that lead to the same burrow or uninhabitable burrows. Eight plots were selected in the barren area and 12 in the vegetated/peat areas. Two plots in the vegetated/peat areas were in areas not currently occupied by puffins, so the final sample was 18 plots. The total breeding population was estimated by multiplying the number of holes by the occupancy rate of these holes. Burrow occupancy rates were also presented for ease of comparison with other studies.

Finally, a number of puffins were observed breeding in crevices of boulders at the periphery of the island. These nests were counted directly while counting Razorbill eggs (see below).

3.2 Razorbills

Breeding Razorbill numbers were estimated by directly counting eggs. All areas of appropriate habitat were searched, which included small cliffs, and rocky and boulder scree. Observers worked in a line moving slowly examining all crevices visually. Observers finding eggs would call out the species of egg (Razorbill or puffin) to a recorder and mark the nest as counted with a small dot of spray paint. This method provided a minimum estimate, as some eggs were likely missed. On Machias Seal Island, New Brunswick, an island with similar areas of boulder scree, Grecian (unpubl. data) obtained a correction factor in 2001 for these inaccessible nests at 29% more nests present than can be counted visually. We provide both uncorrected and corrected estimates for ease of comparisons.

3.3 Leach's Storm-petrel

As previous surveys were not able to accurately delimit the area used by breeding petrels, we established an island wide grid to, 1) determine the limits and area of the petrel breeding areas, and then 2) determine occupied burrow densities. A grid of points where 50 m wide intersecting transects were laid with surveyor's flags across the island. The grid was laid out along magnetic north-south and east-west axes using a compass and distances were measured with tape measures. The starting point for laying out the grid was a point at the western edge of the island that marked the start of the 1984 puffin transect # 1 (AP-1-0 in R.D. Elliot's field notes; CWS files). The UTM coordinates of this point were 22 U 0298827, 5495388.

At each intersection of the 50 m grid, a 16 m^2 circular plot was marked, in the same way as done for puffins. All burrow entrances were counted in each plot, and the contents assessed. In some cases, it was necessary to excavate small observation hatches to accurately assess contents, but this was only done when they could be dug and replaced without doing undue damage to the burrow.

We adopted the following decision rule to improve the resolution of the area occupied by petrels and to ensure that thin strips of petrel breeding habitat at the edge of the island were not missed. If any occupied burrow was found at the intersection of the 50 m x 50 m transects, then eight more plots were assessed, each 25 m from the intersection point (or 35.3 m, in the case of the diagonals, see Figure 3). Further, if another plot could be established 25 m seaward from the 50 m points at the margins of the island, those plots were assessed.

For the analysis, we considered areas where all four corners of the squares of the 50 m intersections that did not have any burrows to be unused habitat. We included areas that did contain burrows as occupied habitat and summed the area of each square (25^2 = 625 m^2) to obtain total occupied burrow area.

In essence each plot represented 16 m^2 of the 625 m^2 square around the plot (or 2.56%). Once occupied area was calculated, burrow density was calculated as the mean of all occupied areas. The occupancy rate was taken as the proportion of occupied burrows to all burrows where the contents could be assessed.

Variances were calculated following Goodman (1960) for the product of two variances from sample means, and the Delta method was used to calculate variances when multiplying a known value with a sample mean.

4. Results

4.1 Atlantic Puffins

4.1.1 2001 Population estimate

Since there was no detectable difference in hole occupancy rates between bare and vegetated plots (t-test, t = 0.45, P = 0.67, df = 16), a global occupied hole rate of 0.697 ± 0.030 was calculated (Table 1). A total of 12 689 holes were counted (5 724 in the bare habitat and 6 985 in vegetated habitats). These numbers produce an estimate of 5 837 ± 355 (95% CI; 5 100 – 6 586) breeding pairs in habitats where burrows could be excavated. An additional 353 breeding pairs were counted directly in boulder and scree habitats around the periphery of the island. Adding these nests gives a final estimate of 6 190 ± 355 (5 453 – 6 939) breeding pairs.

4.1.2 Comparison with earlier surveys

Based on randomly placed plots grubbed in 1984 and 2001, occupied hole rates (t = 5.34, P = 0.001), occupied burrow rates (t = 5.03, P = 0.001) and occupied burrow densities (t = 3.21, P = 0.003) have declined (Table 1). Combined with a reduced number of holes, the breeding population has decreased from 15 000 breeding pairs in

1984 to about 6 000 pairs in 2001. Interestingly, burrow density has not shown a detectable change ($t = 1.33$, $P = 0.19$), and most of the change can be attributed to a lower number of holes present.

It is more difficult to directly compare with earlier surveys, as different methods were used. The 2001 estimate is certainly lower than Cairns and Verspoor's (1980) estimate of 25 000 breeding pairs in 1979. They calculated a burrow occupancy rate of 0.797, 12.5% higher than our estimate. However, this difference alone cannot explain the over 4-fold reduction in the population estimate. The major difference lies in the area occupied by breeding puffins. Cairns and Verspoor (1980) estimated that 34 155 m^2 was occupied by puffins in 1979 and a sketch map of this area is shown in Figure 2. Although we did not measure occupied habitat in the 2001 survey, a comparison of a similar sketch map of occupied area clearly shows that puffins no longer occupy much of the previously used habitat (Figure 2). It appears that puffins are retreating to the periphery of the island, where burrow densities still remain high (Table 1). Similar comparisons can be made with the 1980 estimate of about 20 000 breeding pairs.

Our estimate is also lower than an estimate of 20 000 from 1994 by Russell and Montevecchi (1996), suggesting that the decline in the breeding population has occurred relatively recently.

4.2 Razorbills

4.2.1 2001 Population survey

Razorbills were found nesting in most areas of suitable habitat, with a high concentration of 68 nests in a relatively small area of scree on the northeast corner of the island (Figure 3). Nests were also scattered among the long stretch of boulders running along the east end of the islands, where puffins also nested among the boulders. In all, a total of 193 Razorbill eggs and 1 chick was found, for a total of 194 breeding pairs. This estimate presents a minimum as some eggs were undoubtedly overlooked, so the true population size is likely over 200 breeding pairs. Using Grecian's correction factor of 29% of nests being missed, an estimate of 273 breeding pairs is obtained.

4.2.2 Comparison with earlier surveys

There is no mention of Razorbills in accounts from Peters and Burleigh (1951), Montgomerie's files from 1973, nor from 1979 (Cairns and Verspoor 1980). It is unlikely that Razorbills would have been overlooked, if they were abundant, so it can be assumed that at most a few, and possibly none nested on the islands before 1979. In 1984, R. Elliot found 15 nests (13 eggs and 2 chicks) in the small scree that contained the high density in 2001. Field notes by Elliot explicitly state that other suitable breeding sites were examined and no other eggs or chicks were found. The Razorbill population has increased from about 15 pairs to 194 pairs in 17 years. Assuming a constant rate of increase, this represents a discrete-time deterministic population growth rate of 1.16/yr.

4.3 Leach's Storm-petrel

4.3.1 2001 survey

Of the 20 points that intersected at 50 m intervals, 5 had burrows in the 16 m^2 plot grubbed. Another 25 plots were assessed around these occupied plots, and a further 13 were assessed along the edge of the island. Twenty-one of these 25 m x 25 m (625 m^2) plots contained burrows (Figure 4). We did include one plot, which should have been grubbed, at the south end of the island as part of the occupied area. As these plots occupy 13 750 m^2 of the island, we estimate that 1 038 ± 255 (506 – 1 571) pairs of Leach's Storm-petrels bred on Small Island in 2001.

4.3.2 Comparisons with earlier surveys

Occupancy rates and burrow densities were low in 2001 compared to 1984 and earlier (Table 3). As methods used in other surveys were different, statistical comparisons are not relevant, but it is clear that the petrel population has substantially declined in the last 17 years, if either index is considered. Interestingly, the 1984 survey produced quite a high estimate (Table 4), when both burrow densities and occupancy rates were high (Table 3). Through the mid-1980s, the petrel breeding population may have been growing, or at the very least, stable.

5. Discussion

The numbers of breeding seabirds on Small Island has changed significantly in the last two decades. The burrow-nesting birds, Atlantic Puffins and Leach's Storm-petrels, have declined noticeably, to population sizes to 10%-40% of their levels in the 1980s. Interestingly, over the same period, a healthy breeding population of Razorbills has become established with over 200 breeding pairs.

Several factors may help to explain these dramatic reductions in the population. Changes in the marine ecosystem of the Northwest Atlantic, specifically a reduction in sea surface temperatures, may have affected fish prey species. In Witless Bay, Newfoundland, seabird reproduction was depressed through the 1990s, largely due the late arrival of capelin (*Mallotus villosus*) on shore (Regher and Rodway 1999). However, this reduction in breeding success was mostly shown by the larids; auks and petrels still acheived relatively good reproductive success. In fact, populations of puffins in Witless Bay are believed to be increasing in recent years (Rodway et al. 1996, A. Calvert, unpubl. data). Similarly, in Witless Bay, petrels also showed relatively normal levels of reproductive success in the late 1990s (Stenhouse and Montevecchi 1999) and petrel populations in Witless Bay have not detectably changed in the last 20 years (Stenhouse et al. 2000, Robertson et al. 2002).

Since populations of puffins and petrels at some of the larger colonies in Newfoundland have not shown the same steep decline seen at Small Island, it suggests that this decline is a local effect. There is a gillnet fishery for cod (*Gadus morhua*) in northeastern Newfoundland, which may be impacting local seabirds through bycatch mortality (Piatt and Nettleship 1987). However, petrels would not be caught in gill nets, and any bycatch mortality should impact Razorbills as well as puffins. In fact, Razorbills should be even more vulnerable, as they feed more inshore (Chapdelaine and Brousseau 1996). Although birds may be caught in gill nets, bycatch does not satisfactorily explain a reduction in petrel and puffin numbers, and an expanding Razorbill population.

A decline in food resources due to fishery activity does not satisfactorily explain this pattern either. Large-scale fisheries for forage fishes can have serious consequences for auk reproduction (Brown and Nettleship 1984, Vader et al. 1990, Montevecchi 2002) but puffins and Razorbills, although showing slight differences, generally feed on schooling fish, while petrels feed offshore on myctophid fishes and large zooplancters (Montevecchi et al. 1992). Declines in forage fish resources should impact both puffins and Razorbills, while not necessarily impacting petrels.

A chance event of a mammalian predator present on the island for a summer might explain the decline. This occurs when Arctic Foxes (*Alopex lagopus*) arrive on the island when surrounding waters are covered by ice. Yet, fox predation has been shown to impact all seabirds, especially Razorbills (Birkhead and Nettleship 1995).

An explanation that does satisfactorily explain the decline in puffins and petrels, with a concordant increase in Razorbill numbers, relates to gulls. Russell and Montevecchi (1996) describe the establishment of a colony of Great Black-backed Gulls on Small Island, which occurred between 1979 -1984. In 1984, an estimated 200 Great Black-backed Gulls bred on Small Island, but significant impacts on adult puffins were not noted. In 1994, 683 adult puffin carcasses killed by gulls were collected, and they estimated that 908 puffins were killed on Small Island that summer (Russell and Montevecchi 1996). Overall, Great Black-backed Gulls killed 2.9% of all puffins breeding on the island in 1994 (Russell and Montevecchi 1996). This is in stark contrast to the situation in 1969, when no gulls nested on the island, and puffins enjoyed very high reproductive success (Nettleship 1972).

A reduction in adult survival of 3% could certainly initiate a decline in a local breeding population of puffins, yet is insufficient to explain the apparent 15% annual decline between 1994 and 2001. A plausible scenario is that in conjunction with the direct kill of adults, young puffins may decide not to recruit to a colony where adults are under significant predation risk. Pre-breeding puffins will recruit to colonies other than their natal colonies (Harris 1983). Adult puffins choosing not to invest heavily in reproduction when predation pressure is high may further lower recruitment, as will direct predation by gulls on puffin eggs and chicks. A lack of recruitment would result in a local breeding population declining at the adult mortality rate. As survival rates of puffins range from 0.85 to 0.97 (Harris et al. 1997), a 15% (12% natural mortality and 3% from gulls) decline coincides reasonably well with the adult survival rate. Although adult puffins show strong site tenacity to breeding areas, it is conceivable that adults may move to other colonies when faced with significant predation risk, further decreasing the size of the colony.

This combination of high mortality due to gull predation and reduced recruitment probably holds for petrels, which are often more vulnerable to predation by gulls. Stenhouse et al. (2000) estimated that Great Black-backed and Herring Gulls (*Larus argentatus*) killed 50 000 storm-petrels on Great Island in 1997 and Watanuki (1986) estimated that Slaty-backed Gulls (*L. schistisagus*) killed tens of thousands each month on a Japanese colony. Our estimates of petrel numbers are not as robust as those for puffins, but they strongly suggest that they have substantially declined. As with puffins, pre-breeding petrels do not show natal philopatry (Paterson and Snyder 1999), so there

may have been reduced recruitment to this colony as young birds recruit to safer islands.

Given gull predation is largely responsible for the declines in puffins and petrels, somehow Razorbills have managed to thrive on the island. Great Black-backed Gulls will prey on Razorbill eggs and chicks, yet they do not kill adult Razorbills (Rowe and Jones 2000). Predation of occasional eggs or chicks can apparently be sustained by this breeding Razorbill population. Currently, Razorbills appear to be increasing at all colonies in their North American range (Chapdelaine et al. 2001).

Large gull populations are inflated in many areas, probably due to extra food available in the form of refuse and offal. However, in recent years, many large gull populations are declining as these food sources become reduced (Howes and Montevecchi 1993, Chapdelaine and Rail 1997). Although long-term population trend data for Great Black-backed Gulls are sparse for Newfoundland, they indicate that populations have not changed much in the last 25 years (Cairns and Verspoor 1980, Robertson et al. 2001). Great Black-backed Gulls, puffins and petrels have co-existed for a long time, and co-occur at many colonies. On this colony however, the gulls may be driving puffins and petrels to low numbers and possibly to extinction. At smaller colonies, puffin and petrel numbers may not be high enough to withstand gull predation.

Both puffins and gulls are recent colonists to Small Island. Puffin numbers did not reach large numbers until the 1970s, while gulls began nesting on the island between 1979 and 1984. A longer-term dynamic may be occurring, where puffins become established at a colony and gulls follow some years later. Where puffin (or petrel) numbers are large enough, an equilibrium between predators and prey is reached. However, if gull numbers are too large, and puffin/petrel numbers low, then the colony may go extinct, while other puffin/petrel colonies become established on other islands. Anthropogenic influences may destabilize these equilibria, and in these cases artificially high predator numbers may drive the prey population to low levels. Before 1979, Arctic (*Sterna paradisaea*) and Common Terns (*S. hirundo*) bred on Small Island in large numbers (Nettleship 1972, Cairns and Verspoor 1980), however, as of 1979, very few bred on this island. After gulls colonize an island, terns may be the first species to move to other islands, with puffins and petrels to follow.

In contrast to the larger colonies in Newfoundland, petrels and puffins are declining on Small Island, while Razorbills are showing the same increases seen in many colonies. These differences highlight the importance of monitoring more than one colony, as different trends may occur at any one. We attribute these population changes to the actual and perceived predation risk from large gulls, but other factors could also play a role. The next step would be to assess other local colonies of puffins and petrels, to see if other nearby islands are being colonized and are increasing. In a natural system, various seabird colonies would be increasing, stable or decreasing; when more colonies are decreasing than increasing, action may be warranted.

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7. Literature Cited

Birkhead, T. R., and D. N. Nettleship. 1995. Arctic fox influence on a seabird community in Labrador: a natural experiment. Wils. Bull. 107: 397-412.

Brown, R. G. B., and D. N. Nettleship. 1984. Capelin and seabirds in the Northwest Atlantic. Pages 184-195 *in* D. N. Nettleship, G. A. Sanger and P. F. Springer (eds.), Marine birds: their feeding ecology and commercial fishery relationships. Can. Wildl. Serv. Special Publ., Ottawa.

Cairns, D. and E. Verspoor. 1980. Surveys of Newfoundland seabird colonies in 1979. Unpublished Can. Wildl. Serv. Report. Sackville, NB.

Cairns, D. K., W. A. Montevecchi and W. Threlfall. 1989. Researcher's guide to Newfoundland seabird colonies. Memorial University of Newfoundland, Occasional Papers in Biology No 14. St. John's, NF.

Chapdelaine, G., and P. Brousseau. 1996. Diet of Razorbill *Alca torda* chicks and breeding success in the St. Mary's Islands, Gulf of St. Lawrence, Québec, Canada. Pages 27-37 *in* W. A. Montevecchi (ed.), Studies of high latitude seabird. 4. Trophic relationships and energetics of endotherms in cold ocean systems. Can. Wildl. Serv. Occ. Pap. Ser. No. 91, Ottawa.

Chapdelaine, G., and J.-F. Rail. 1997. Relationship between cod fishery activity and the population of herring gulls on the North Shore of the Gulf of St. Lawrence, Québec, Canada. ICES J. Mar. Sci. 54: 708-713.

Chapdelaine, G., A. W. Diamond. R. D. Elliot and G. J. Robertson. 2001. Status and population trends of the Razorbill in eastern North America. Can. Wildl. Serv. Occ. Pap. No. 105, Ottawa.

Goodman, L. A. 1960. On the exact variances of products. Journal American Statistical Association 55: 708-713.

Harris, M. P. 1983. Biology and survival of the immature Puffin *Fratercula arctica*. Ibis 125: 56-73.

Harris, M. P., S. N. Freeman, S. Wanless, B. J. T. Morgan, and C. V. Wernham. 1997. Factors influencing the survival of Puffins *Fratercula arctica* at a North Sea colony over a 20-year period. J. Avian Biol. 28: 287-295.

Howes, L.-A., and W. A. Montevecchi. 1993. Population trends and interactions among terns and gulls in Gros Morne National Park, Newfoundland. Can. J. Zool. 71: 1516-1520.

Montevecchi, W. A. 2002. Interactions between fisheries and seabirds. Pages 527-557 *in* E.A. Schreiber and J. Burger (eds.), Biology of Marine Birds. CRC Press, Boca Raton, FL.

Montevecchi, W. A., and L. M. Tuck. 1987. Newfoundland birds: exploitation, study, conservation. Nuttall Ornithological Club, Cambridge, MA.

Montevecchi, W. A., V. L. Birt-Friesen and D. K. Cairns. 1992. Reproductive energetics and prey harvest of Leach's Storm-petrel in the North Atlantic. Auk 109: 823-832.

Nettleship, D. N. 1972. Breeding success of the Common Puffin (*Fratercula arctica* L.) on different habitats at Great Island, Newfoundland. Ecological Monographs 42: 239-268.

Paterson, I. G., and M. Snyder. 1999. Molecular genetic (RAPD) analysis of Leach's Storm-petrels. Auk 116: 338-344.

Peters, H. S. and T. D. Burleigh. 1951. The birds of Newfoundland. Newfoundland Dept. Nat. Resour., St. John's, NF.

Piatt, J. F., and D. N. Nettleship. 1987. Incidental catch of marine birds and mammals in fishing nets off Newfoundland, Canada. Mar. Poll. Bull. 18: 344-349.

Regehr, H. R. and M. S. Rodway. 1999. Seabird breeding performance during two years of delayed capelin arrival in the Northwest Atlantic: a multi-species comparison. Waterbirds 22: 60-67.

Robertson, G. J., D. Fifield, M. Massaro and J.W. Chardine. 2001. Changes in nesting-habitat use of large gulls breeding in Witless Bay, Newfoundland. Can. J. Zool. 79: 2159-2167.

Robertson, G. J., J. Russell and D. Fifield. 2002. Breeding population estimates for three Leach's Storm-petrel colonies in southeastern Newfoundland, 2001. Can. Wildl. Serv. Tech. Rep. Ser. No. 380, Atlantic Region, Mount Pearl, NF.

Rodway, M. S., H. R. Regehr, and J. W. Chardine. 1996. Population census of breeding Atlantic Puffins at Great Island, Newfoundland in 1993-1994. Can. Wildl. Serv. Tech. Rep. Ser. No. 263, Atlantic Region. Sackville, NB.

Rowe, S., and I.L. Jones. 2000. The enigma of Razorbill *Alca torda* breeding site selection: adaptation to a variable environment? Ibis 142: 324-327.

Russell, J., and W. A. Montevecchi. 1996. Predation on adult Puffins *Fratercula arctica* by Great Black-backed Gulls *Larus marinus* at a Newfoundland colony. Ibis 138: 791-794.

Stenhouse, I. J., and W. A. Montevecchi. 1999. Indirect effects of the availability of forage fish and fisheries discards: gull predation on breeding storm-petrels. Marine Ecol. Prog. Series 184: 303-327.

Stenhouse, I. J., G. J. Robertson and W. A. Montevecchi. 2000. Herring Gull *Larus argentatus* predation on Leach's Storm-petrels *Oceanodroma leucorhoa* breeding on Great Island, Newfoundland. Atlantic Seabirds 2:35-44.

Vader, W., R. T. Barrett, K. E. Erikstad and K.-B. Strann. 1990. Differential responses of Common and Thick-billed Murres to a crash in capelin stock in the southern Barents Sea. Stud. Avian Biol. 14:175-180.

Watanuki, Y. 1986. Moonlight avoidance behavior in Leach's Storm-petrel as a defense against Slaty-backed Gulls. Auk 103:14-22.

Table 1. Occupancy rates and burrow densities (± 1 SE with 95% CI in parentheses) of Atlantic Puffins breeding on Small Island, Wadham Islands, Newfoundland.

	1973	1979	1980	1984	1994	2001
Sample size		7	17	25	10 / 11	18
Occupied hole rate				0.693 ± 0.031 (0.629 – 0.757)		0.460 ± 0.028 (0.402 – 0.519)
Occupied burrow rate	0.6[a]	0.797 (0.72 – 0.89)	0.756 ± 0.058 (0.633 - 0.879)	0.877 ± 0.021 (0.834 – 0.920)		0.697 ± 0.030 (0.632 – 0.762)
Burrow density (m^2)	1.37	0.92	0.786 ± 0.076 (0.626 - 0.946)	1.161 ± 0.070 (1.016 – 1.306)		1.022 ± 0.076 (0.861 – 1.182)
Occupied burrow density (m^2)			0.594 ± 0.073 (0.439 – 0.749)	0.975 ± 0.068 (0.835 – 1.115)	1.83 ± 0.33 / 0.71 ± 0.48	0.678 ± 0.055 (0.563 – 0.793)
Hole count				21 600		12 689

NOTE: 1973 data from CWS files based on R. Montgomerie's notes; 1979 information from Cairns and Verspoor (1980); 1980 from CWS files; 1984 data from CWS files based on R. D. Elliot's notes; 1994 information from Russell and Montevecchi (1996). For 1994, the habitat was visually divided into high or low density habitat (before and after slashes).

[a] assumed occupancy rate

Table 2. Population estimates for Atlantic Puffins breeding on Small Island, Wadham Islands, Newfoundland.

Year	Method	Estimate (pairs)
1945	Visual estimate (Coleman and Small Is. combined)	2 500
1969	Visual estimate (minimum)	1 500
1973	Occupied habitat and burrow density (occupancy rate assumed)	4 477
1979	Occupied habitat and occupied burrow density	25 118
1980	Occupied habitat and occupied burrow density	20 290
1984	Total hole count and occupancy rate	14 969
1994	Occupied habitat and occupied burrow density	19 745
2001	Total hole count and occupancy rate	6 190

NOTE: 1945 estimate from Peters and Burleigh (1951) and 1969 estimate from Nettleship (1972). Otherwise same sources as Table 1.

Table 3. Occupancy rates and burrow densities (± 1 SE) of Leach's Storm-petrel breeding on Small Island, Wadham Islands, Newfoundland.

	1973	1979	1984	2001
Number of plots	13	7	39	21
Number of plots where occupancy rates assessed	-	-	25	20
Occupied burrow rate	0.6[a]	0.429 (0.29 - 0.58)	0.690 ± 0.046 (0.595 – 0.784)	0.338 ± 0.089 (0.152 – 0.525)
Burrow density (m^2)	0.87	0.45	0.507 ± 0.097 (0.306 - 0.707)	0.223 ± 0.039 (0.143 – 0.304)
Occupied burrow density (m^2)			0.350 ± 0.084 (0.176 – 0.523)	0.076 ± 0.019 (0.037 – 0.114)

NOTE: data from same sources as Table 1

[a] assumed occupancy rate

Table 4. Population estimates for Leach's Storm-petrel breeding on Small Island, Wadham Islands, Newfoundland.

Year	Method	Estimate (pairs)
1945	Visual estimate (Coleman and Small Is. combined)	3 000
1973	Occupied habitat and burrow density (occupancy rate assumed)	1 975
1979	Occupied habitat and occupied burrow density (occupied area assumed)	6 566
1984	Occupied habitat and occupied burrow density (occupied area assumed)	11 938
2001	Occupied habitat and occupied burrow density	1 038

NOTE: data from same sources as Table 1 and 2

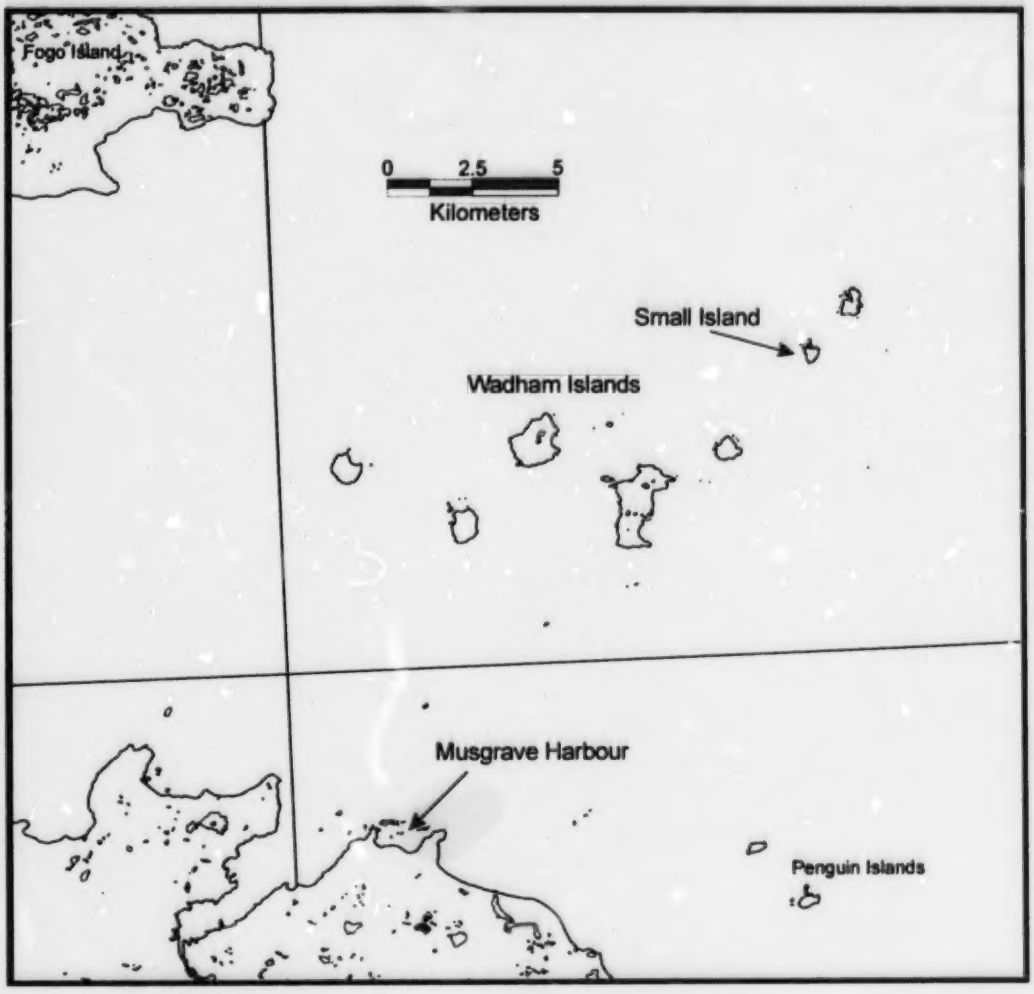

Figure 1. Location of Small Island, Wadham Islands, Newfoundland.

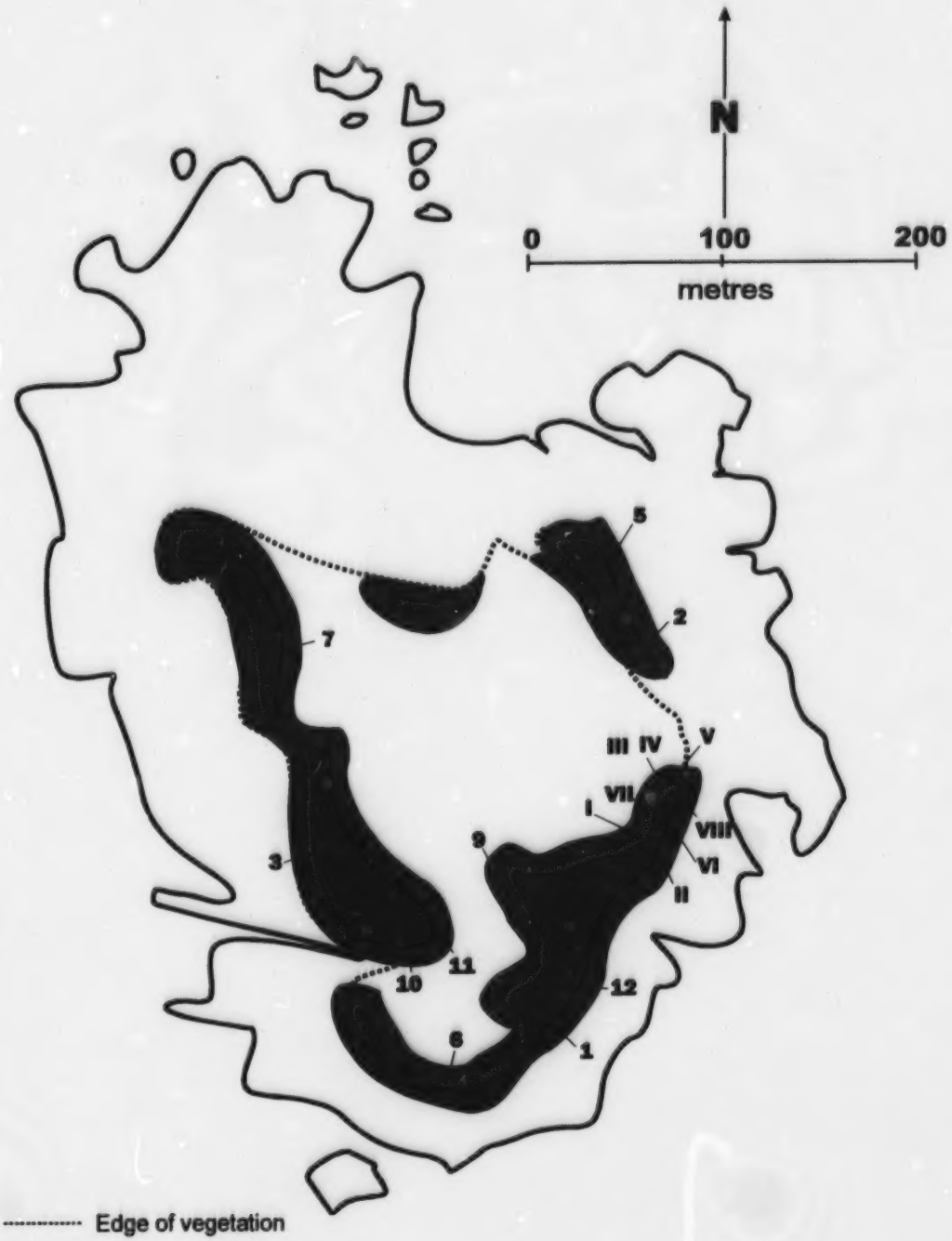

Figure 2. Location of randomly selected Atlantic Puffin occupancy plots in 2001 on Small Island, Newfoundland. Light grey areas indicate habitat occupied by breeding puffins in 1979, while darker grey areas represent the reduced breeding distribution in 2001. Letters correspond to areas where holes counted.

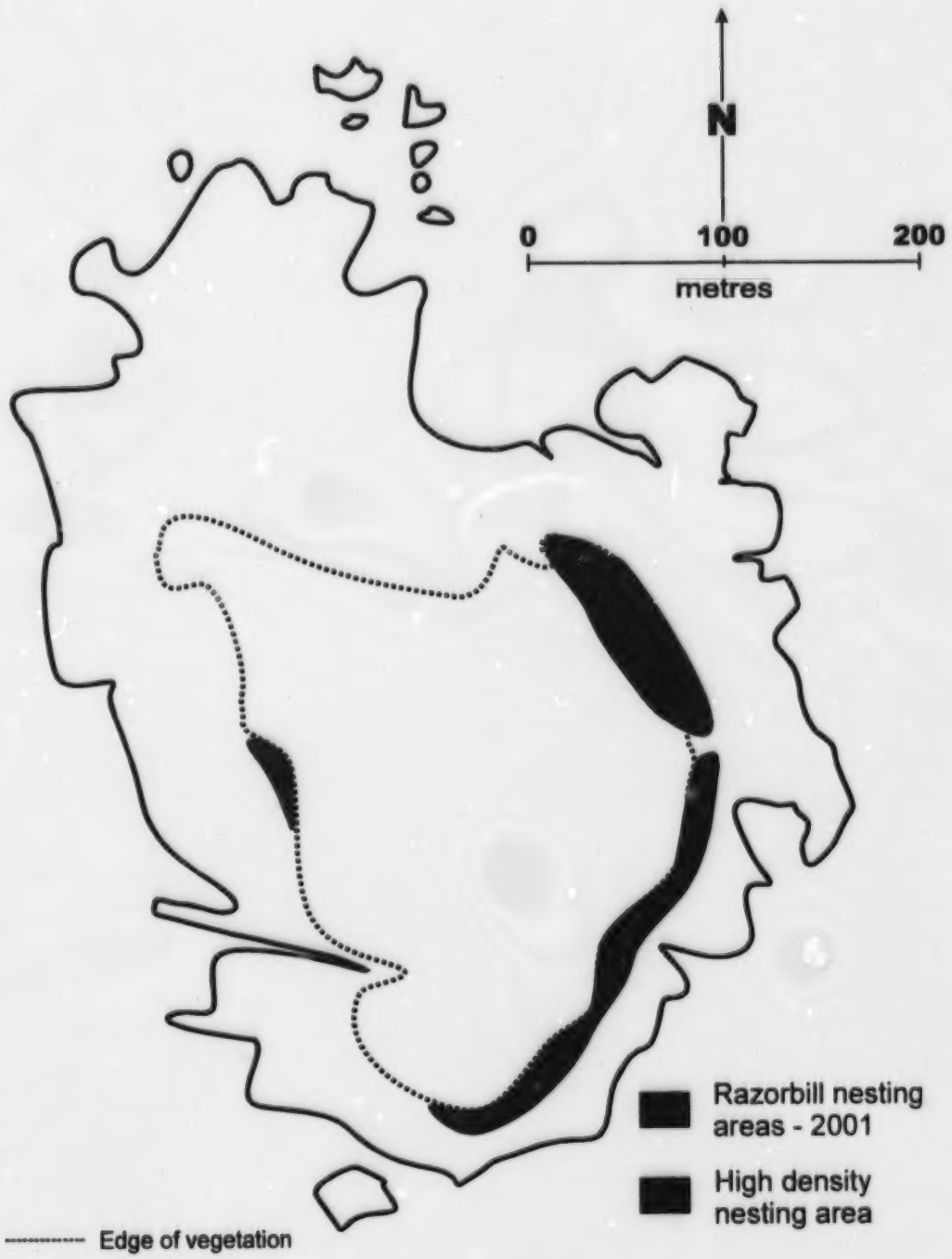

Figure 3. Location of breeding Razorbills, Small Island, Newfoundland in 2001.

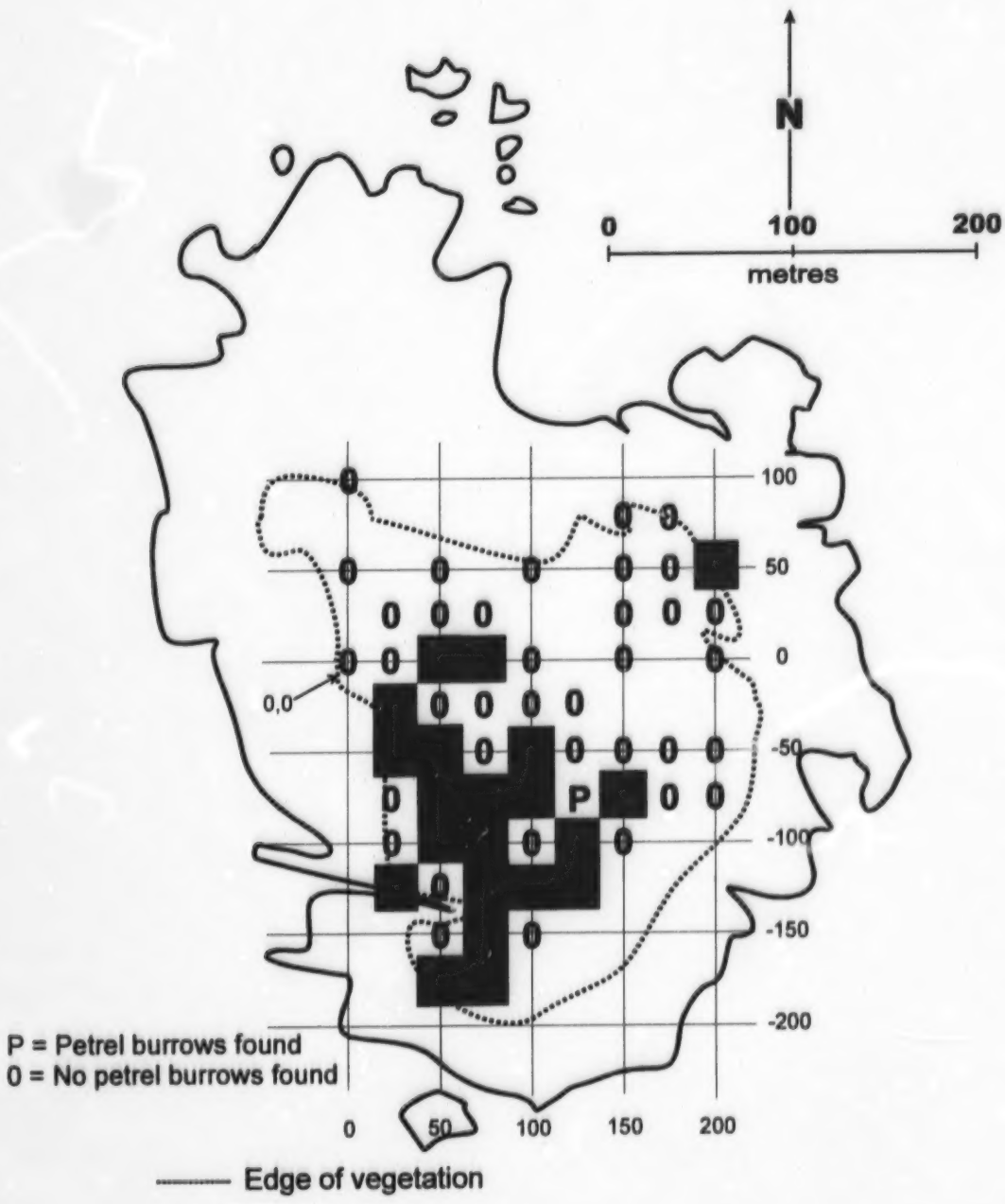

Figure 4. Distribution of plots in which petrel occupancy was assessed in 2001, on Small Island, Newfoundland. Grey areas are those considered occupied for calculation of total population size.

Appendix 1.1. Raw burrow density and occupancy data for Atlantic Puffins breeding on Small Island, 2001. Plots were selected as random points within puffin nesting habitat. All plots are 30 m^2.

Plot	Bare/ vegetated	Short	Empty	Entrance	Egg	Egg/ adult	Chick	Chick/ adult	Adult	Nest material	Unknown	Date
5	Vegetated	6	1	5	5	5	0	0	0	1	0	6 July
2	Vegetated	2	12	13	4	9	0	0	0	0	1	6 July
V	Bare	10	8	14	8	13	0	0	0	0	0	6 July
IV	Bare	1	9	14	11	14	0	0	1	0	2	6 July
VII	Bare	7	2	8	11	11	0	0	0	0	0	6 July
VI	Bare	11	10	31	6	8	0	0	0	0	3	6 July
III	Bare	1	13	11	15	6	0	0	4	0	2	6 July
VII	Bare	0	11	14	15	12	0	0	0	0	5	6 July
II	Bare	1	12	7	7	5	0	0	2	0	5	6 July
I	Bare	10	5	6	13	5	0	0	1	0	0	6 July
9	Vegetated	0	4	4	6	0	0	0	0	0	2	6 July
12	Vegetated	4	8	7	8	14	0	0	2	0	4	6 July
1	Vegetated	2	7	3	14	6	0	0	0	0	1	6 July
6	Vegetated	1	10	0	1	5	0	0	0	0	0	6 July
10	Vegetated	2	7	3	3	4	0	0	1	0	2	6 July
11	Vegetated	1	2	0	1	0	0	0	1	0	0	6 July
3	Vegetated	3	6	8	10	10	0	0	2	0	4	6 July
7	Vegetated	1	2	7	8	5	0	0	2	0	2	6 July

Appendix 1.2. Hole counts for puffin breeding areas on Small Island, see Figure 2 for locations of these areas.

Area	Holes counted
B	1548
C	5724
D	2589
E	271
F	1396
G	1161

Appendix 2. Raw burrow density and occupancy data for Atlantic Puffins breeding on Small Island, 1984. Locations of plots were based on previously established transects (Cairns and Verspoor 1980). The Montgomerie transect (Mont) was established in 1973, while AP-1 and AP-2 were established in 1979 and 1980 respectively. The final number in the plot name represents the distance (in m) along the transect. The random plots were selected as random points within petrel nesting habitat. Only the random plots were used to calculate occupied burrow densities in this paper. Transect based plots were 25 m^2 while random plots are 30 m^2.

Plot	Short	Empty	Entrance	Egg	Egg/ adult	Chick	Chick/ adult	Adult	Nest Material	Unknown	Date
Transect based											
Mont-5	0	2	2	6	6	0	0	2	3	4	9 July
Mont-10	0	0	0	0	0	0	0	0	0	0	9 July
Mont-15	0	2	0	3	1	0	0	3	2	1	9 July
Mont-20	0	0	0	0	0	0	0	0	0	0	9 July
Mont-25	1	2	1	7	5	0	0	1	0	3	9 July
Mont-30	0	0	0	0	0	0	0	0	0	0	9 July
Mont-35	0	3	1	3	2	0	0	2	3	3	9 July
Mont-40	0	0	0	0	0	0	0	0	0	0	10 July
Mont-45	0	1	6	7	7	0	0	2	3	3	10 July
Mont-50	0	0	0	0	0	0	0	0	0	0	10 July
Mont-55	1	0	7	9	10	0	0	3	3	1	10 July
Mont-60	0	0	0	0	0	0	0	0	0	0	10 July
Mont-65	1	0	6	6	12	0	0	2	0	1	10 July
Mont-70	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-5	2	3	1	9	6	0	0	3	1	5	10 July
AP-1-10	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-15	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-20	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-25	1	1	11	12	10	0	0	9	2	6	10 July
AP-1-30	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-35	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-40	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-45	0	3	5	5	1	0	0	1	2	3	10 July
AP-1-50	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-55	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-60	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-65	0	4	3	2	3	0	0	0	0	1	10 July
AP-1-70	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-75	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-80	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-85	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-90	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-95	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-100	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-105	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-110	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-115	0	1	0	2	1	0	0	0	0	3	11 July
AP-1-120	0	0	0	0	0	0	0	0	0	0	11 July

AP-1-125	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-130	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-135	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-140	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-145	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-150	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-155	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-160	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-165	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-170	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-175	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-180	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-185	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-190	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-195	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-200	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-205	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-210	1	0	1	2	4	0	0	0	0	0	11 July
AP-1-215	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-220	1	3	2	4	1	0	0	0	0	1	11 July
AP-2-5	1	0	3	7	1	0	0	1	3	3	11 July
AP-2-10	1	1	6	11	7	0	0	2	0	5	11 July
AP-2-15	0	0	0	0	0	0	0	0	0	0	11 July
AP-2-20	0	0	0	0	0	0	0	0	0	0	11 July
AP-2-25	1	6	6	9	2	0	0	3	3	4	11 July
AP-2-30	0	0	0	0	0	0	0	0	0	0	11 July
AP-2-35	0	0	0	0	0	0	0	0	0	0	11 July
AP-2-40	0	0	0	0	0	0	0	0	0	0	11 July
AP-2-45	0	6	8	13	0	0	0	2	1	7	12 July
AP-2-50	1	2	7	7	2	0	0	5	1	4	11 July
AP-2-55	0	0	0	0	0	0	0	0	0	0	11 July
AP-2-60	0	0	0	0	0	0	0	0	0	0	11 July
AP-2-65	0	7	7	3	6	0	0	0	0	1	12 July
AP-2-70	0	5	1	5	3	0	0	2	0	1	11 July
AP-2-75	0	0	0	0	0	0	0	0	0	0	11 July
AP-2-80	0	0	0	0	0	0	0	0	0	0	11 July
AP-2-85	0	4	2	3	3	0	0	0	1	0	12 July
AP-2-90	4	4	0	7	6	0	0	1	0	0	11 July
AP-2-95	0	0	0	0	0	0	0	0	0	0	11 July
AP-2-100	0	0	0	0	0	0	0	0	0	0	11 July
AP-2-105	0	4	4	7	4	0	0	1	0	0	12 July
AP-2-110	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-115	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-120	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-125	0	0	1	13	7	0	0	1	0	1	12 July
AP-2-130	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-135	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-140	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-145	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-150	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-155	0	0	0	0	0	0	0	0	0	0	12 July

AP-2-160	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-165	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-170	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-175	0	1	0	9	11	0	0	8	2	0	12 July
AP-2-180	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-185	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-190	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-195	2	2	3	7	10	0	0	5	1	0	12 July
AP-2-200	0	0	0	0	0	0	0	0	0	0	12 July
Random plots											
19	0	1	6	11	11	1	0	16	3	1	14 July
21	0	1	3	18	10	0	0	3	1	4	14 July
5	2	1	2	14	4	0	0	4	0	0	14 July
8	0	2	3	12	0	0	0	3	3	0	14 July
14	5	9	15	12	2	0	0	5	1	5	14 July
23	1	3	8	17	9	0	2	7	2	3	14 July
22	0	1	0	7	4	0	1	5	1	2	14 July
13	0	4	0	2	2	0	1	2	0	1	14 July
4	2	5	10	12	6	0	1	6	1	9	14 July
10	1	1	5	14	3	2	1	11	4	2	14 July
16	0	4	9	9	4	0	0	6	3	1	14 July
24	6	3	8	18	1	0	0	3	3	2	14 July
3	2	2	11	19	5	1	2	5	3	2	14 July
25	5	6	26	20	6	2	0	9	1	0	14 July
20	2	4	7	21	3	0	1	15	2	2	14 July
6	0	7	7	11	2	0	0	3	1	2	15 July
18	1	2	1	9	0	0	0	1	0	2	15 July
2	1	1	1	11	0	0	0	2	4	2	15 July
9	0	4	6	7	5	0	0	4	3	3	15 July
11	3	6	6	5	1	0	0	1	0	2	15 July
15	1	4	3	9	4	0	0	6	0	1	15 July
1	0	2	1	5	0	0	0	5	0	3	15 July
17	0	0	1	10	9	0	1	2	0	1	15 July
12	1	1	4	10	4	0	0	8	1	0	15 July
7	1	2	8	10	7	0	0	11	0	4	15 July

Appendix 3. Raw burrow density and occupancy data for Leach's Storm-petrels breeding on Small Island, 2001. Locations of plots are based on the deviation from UTM coordinates 22 U 0298827, 5495388. All plots are 16 m^2.

Easting (m)	Northing (m)	Total Burrows	Empty	Entrances	Occupied	Unknown	Date
0	0	0	0	0	0	0	7 July
50	0	6	0	0	1	0	7 July
100	0	0	0	0	0	0	7 July
150	0	0	0	0	0	0	7 July
200	0	0	0	0	0	0	7 July
200	-50	0	0	0	0	0	7 July
150	-50	0	0	0	0	0	7 July
100	-50	3	2	0	1	0	7 July
50	-50	1	1	0	0	0	7 July
50	-100	13	2	0	3	3	7 July
100	-100	0	0	0	0	0	7 July
150	-100	0	0	0	0	0	7 July
100	-150	0	0	0	0	0	7 July
50	-150	0	0	0	0	0	7 July
50	-175	3	0	0	1	2	7 July
75	-175	3	0	0	3	0	7 July
50	-125	0	0	0	0	0	7 July
25	-125	4	0	0	2	2	7 July
25	-100	0	0	0	0	0	7 July
75	-100	6	1	0	1	3	7 July
75	-125	1	1	0	0	0	7 July
50	-75	4	2	0	0	2	7 July
25	-75	0	0	0	0	0	7 July
25	-50	5	1	0	0	4	7 July
25	-25	3	2	0	0	1	7 July
50	-25	0	0	0	0	0	7 July
75	-25	0	0	0	0	0	7 July
75	0	5	2	2	1	0	7 July
75	25	0	0	0	0	0	7 July
50	25	0	0	0	0	0	7 July
25	25	0	0	0	0	0	7 July
25	0	0	0	0	0	0	7 July
0	50	0	0	0	0	0	7 July
0	100	0	0	0	0	0	7 July
50	50	0	0	0	0	0	7 July
100	50	0	0	0	0	0	7 July
150	50	0	0	0	0	0	7 July
150	75	0	0	0	0	0	7 July
200	50	7	3	0	0	3	7 July
175	75	0	0	0	0	0	8 July
175	50	0	0	0	0	0	8 July
200	25	0	0	0	0	0	8 July
175	25	0	0	0	0	0	8 July
200	-25	0	0	0	0	0	8 July
200	-75	0	0	0	0	0	8 July

175	-50	0	0	0	0	0	8 July
175	-75	0	0	0	0	0	8 July
150	-75	2	1	1	0	0	8 July
125	-100	2	1	2	1	0	8 July
125	-125	1	1	0	0	0	8 July
100	-125	2	1	0	1	0	8 July
125	-50	0	0	0	0	0	8 July
125	-75	1	0	0	0	1	8 July
100	-75	2	1	0	0	1	8 July
75	-75	1	1	1	0	0	8 July
75	-50	0	0	0	0	0	8 July
75	-25	0	0	0	0	0	8 July
100	-25	0	0	0	0	0	8 July
125	-25	0	0	0	0	0	8 July

Appendix 4. Raw burrow density and occupancy data for Leach's Storm-petrels breeding on Small Island, 1984. Locations of plots were based on previously established transects (Cairns and Verspoor 1980). The Montgomerie transect (Mont) was established in 1973, while AP-1 and AP-2 were established in 1979 in 1980 respectively. The final number in the plot name represents the distance (in m) along the transect. The random plots were selected as random points within petrel nesting habitat. Only the random plots were used to calculate occupied burrow densities in this paper. Transect based plots were 25 m^2 while random plots are 30 m^2.

Plot	Short	Empty	Entrance	Egg	Egg/ adult	Chick	Chick/ adult	Adult	Nest material	Unknown	Date
Transect based											
Mont-5	0	2	0	0	1	0	0	1	1	6	9 July
Mont-10	0	0	0	0	0	0	0	0	0	0	9 July
Mont-15	0	3	1	0	2	0	0	0	0	4	9 July
Mont-20	0	0	0	0	0	0	0	0	0	0	9 July
Mont-25	0	3	2	1	0	0	0	3	0	9	9 July
Mont-30	0	0	0	0	0	0	0	0	0	0	9 July
Mont-35	0	1	0	0	3	0	0	3	1	5	9 July
Mont-40	0	0	0	0	0	0	0	0	0	0	10 July
Mont-45	0	1	3	0	1	0	0	1	2	3	10 July
Mont-50	0	0	0	0	0	0	0	0	0	0	10 July
Mont-55	0	0	0	0	0	0	0	0	0	2	10 July
Mont-60	0	0	0	0	0	0	0	0	0	0	10 July
Mont-65	1	1	0	0	0	0	0	0	0	1	10 July
Mont-70	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-5	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-10	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-15	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-20	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-25	2	2	1	0	3	0	0	0	0	5	10 July
AP-1-30	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-35	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-40	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-45	4	3	1	2	6	0	0	2	0	7	10 July
AP-1-50	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-55	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-60	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-65	1	1	1	0	0	0	0	0	1	2	10 July
AP-1-70	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-75	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-80	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-85	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-90	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-95	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-100	0	0	0	0	0	0	0	0	0	0	10 July
AP-1-105	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-110	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-115	0	1	1	0	0	0	0	0	0	3	11 July
AP-1-120	0	0	0	0	0	0	0	0	0	0	11 July

AP-1-125	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-130	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-135	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-140	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-145	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-150	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-155	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-160	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-165	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-170	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-175	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-180	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-185	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-190	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-195	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-200	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-205	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-210	0	3	0	0	0	0	0	0	0	1	11 July
AP-1-215	0	0	0	0	0	0	0	0	0	0	11 July
AP-1-220	0	1	1	0	0	0	0	0	0	3	11 July
AP-2-5	1	3	4	0	0	0	0	0	2	7	11 July
AP-2-10	3	1	3	1	0	0	0	2	0	7	11 July
AP-2-15	0	0	0	0	0	0	0	0	0	0	11 July
AP-2-20	0	0	0	0	0	0	0	0	0	0	11 July
AP-2-25	0	0	2	0	0	0	0	2	4	14	11 July
AP-2-30	0	0	0	0	0	0	0	0	0	0	11 July
AP-2-35	0	0	0	0	0	0	0	0	0	0	11 July
AP-2-40	0	0	0	0	0	0	0	0	0	0	11 July
AP-2-45	2	0	2	0	0	0	0	1	2	10	12 July
AP-2-50	1	1	3	0	0	0	0	0	0	13	11 July
AP-2-55	0	0	0	0	0	0	0	0	0	0	11 July
AP-2-60	0	0	0	0	0	0	0	0	0	0	11 July
AP-2-65	0	0	1	1	0	0	0	1	1	2	12 July
AP-2-70	0	2	1	0	1	0	0	0	0	3	11 July
AP-2-75	0	0	0	0	0	0	0	0	0	0	11 July
AP-2-80	0	0	0	0	0	0	0	0	0	0	11 July
AP-2-85	1	3	3	1	0	0	0	3	2	3	12 July
AP-2-90	1	1	3	1	0	0	0	0	0	10	11 July
AP-2-95	0	0	0	0	0	0	0	0	0	0	11 July
AP-2-100	0	0	0	0	0	0	0	0	0	0	11 July
AP-2-105	2	2	1	0	0	0	0	0	0	8	12 July
AP-2-110	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-115	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-120	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-125	0	0	2	0	0	0	0	0	0	1	12 July
AP-2-130	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-135	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-140	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-145	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-150	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-155	0	0	0	0	0	0	0	0	0	0	12 July

AP-2-160	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-165	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-170	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-175	0	0	0	1	0	0	0	0	1	2	12 July
AP-2-180	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-185	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-190	0	0	0	0	0	0	0	0	0	0	12 July
AP-2-195	2	0	1	0	0	0	0	0	0	1	12 July
AP-2-200	0	0	0	0	0	0	0	0	0	0	12 July
Random plots											
19	0	0	0	0	0	0	0	0	0	2	14 July
21	1	2	1	2	0	0	0	1	0	6	14 July
5	0	0	0	0	0	0	0	0	0	0	14 July
8	0	0	3	1	2	0	0	2	0	8	14 July
14	0	0	0	0	0	0	0	0	0	1	14 July
23	0	0	1	0	0	0	0	0	0	3	14 July
22	0	1	0	2	0	0	0	1	1	13	14 July
13	0	2	3	0	1	0	0	3	0	14	14 July
4	0	2	1	0	1	0	0	1	0	8	14 July
10	0	0	0	0	0	0	0	0	0	1	14 July
16	1	0	0	0	2	0	0	2	0	0	14 July
24	0	0	0	0	0	0	0	0	0	0	14 July
3	0	0	0	0	0	0	0	0	0	0	14 July
25	0	0	0	0	0	0	0	0	0	0	14 July
20	0	0	0	0	0	0	0	1	0	0	14 July
6	3	10	15	2	0	0	0	6	0	21	15 July
18	6	5	2	0	0	0	0	3	2	34	15 July
2	10	6	4	1	0	0	0	0	0	23	15 July
9	2	4	3	1	0	0	0	3	0	10	15 July
11	5	4	5	1	0	0	0	1	1	16	15 July
15	0	2	0	1	0	0	0	1	0	2	15 July
1	2	1	2	1	6	0	0	7	0	9	15 July
17	0	0	0	0	0	0	0	0	0	0	15 July
12	0	0	0	0	0	0	0	1	0	0	15 July
7	0	0	0	0	0	0	0	0	0	0	15 July
i	0	2	0	0	0	0	0	1	0	0	15 July
ii	0	0	0	0	0	0	0	0	0	0	15 July
iii	0	0	0	0	0	0	0	0	0	0	15 July
v	0	0	0	0	0	0	0	0	0	0	15 July
vi	2	1	1	0	1	0	0	1	1	2	15 July
viii	0	0	0	0	0	0	0	0	0	0	15 July
x	0	0	0	0	0	0	0	0	0	0	15 July
viii	1	12	8	10	5	0	0	27	1	7	16 July
ix	1	5	1	1	0	0	0	7	0	0	17 July
vi	1	5	1	2	0	0	0	12	0	3	17 July
26	7	9	8	6	16	0	0	33	0	3	16 July
27	2	10	6	9	4	0	0	8	0	5	16 July
28	0	6	1	3	2	0	0	22	0	10	16 July
29	1	6	0	6	2	0	0	17	2	3	16 July
30	24	4	3	2	0	0	0	16	2	10	16 July